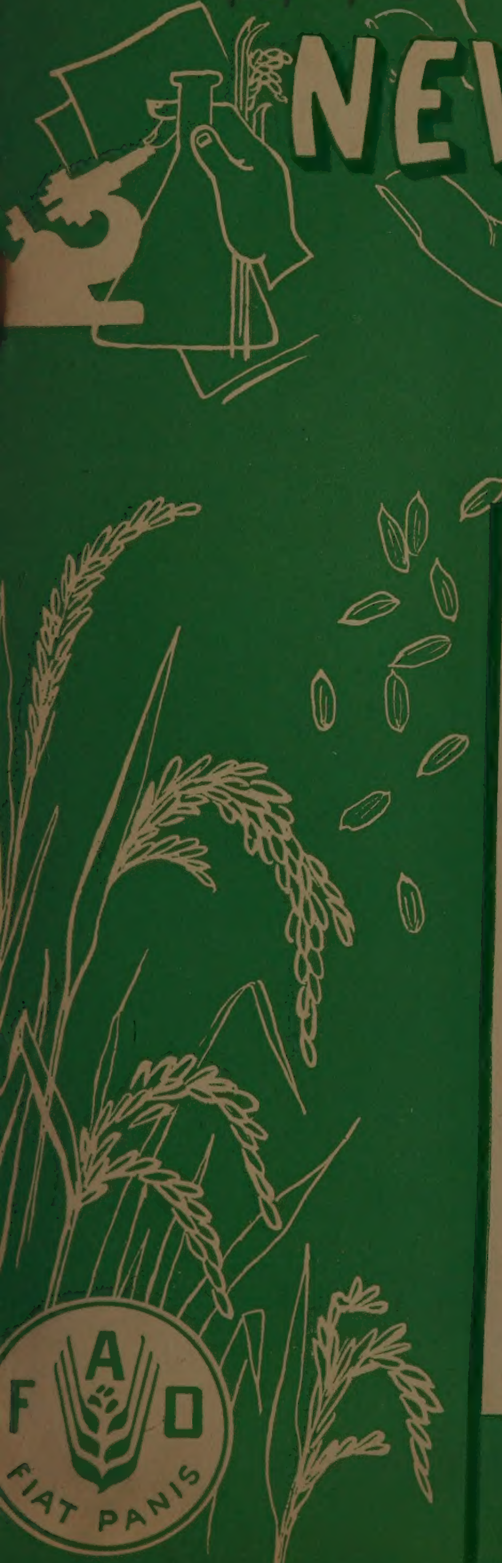
INTERNATIONAL RICE COMMISSION

NEWSLETTER



Vol. VIII, No. 3 September, 1959

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FOOD AND AGRICULTURE ORGANIZATION
REGIONAL OFFICE FOR ASIA AND THE FAR EAST
BANGKOK THAILAND

PROGRESS IN WEED CONTROL IN RICE PRODUCTION IN THE UNITED STATES[1]

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Rice is grown under conditions very favourable for the growth and reproduction of aquatic and semiaquatic weeds. Most weeds that infest rice fields produce an abundance of viable seed and once the soil is infested their removal is difficult. The best approach to weed control in rice is to prevent weed infestations. This may be accomplished by seeding weed-free rice seed and removing scattered weed seedlings from the field before they produce seed. However, after the soil becomes infested with weeds, they may be effectively and economically controlled by using certain cultural and chemical methods.

Weeds compete with rice for light, nutrients, water, and space. If not controlled adequately, they reduce yields and lower the market value of the crop by reducing its quality. Weeds also increase harvesting and drying problems.

Serious weeds which cause losses in rice include: barnyardgrass (**Echinochloa** spp.), red rice (**Oryza sativa** L.), coffeeweed (**Sesbania exaltata** (Raf.) Cory), curly indigo (**Aeschynomene virginica** L.)BSP.), Mexican weed (**Caperonia castaneaefolia** L. St. Hil.), mudplantain (**Heteranthera** spp.), arrowhead (**Sagittaria** spp.), gooseweed (**Sphenoclea zeylanica** Gaertn.), redstem (**Ammannia coccinea** Rottb.), bulrush (**Scirpus** spp.,) umbrella-sedge (**Cyperus** spp.), and spikerush (**Eleocharis** spp.).

Barnyardgrass is a serious problem throughout the rice-growing areas of the United States. Yields of rice may be reduced one-half to one-fourth or even more by barnyardgrass. Each year yields are reduced significantly by barnyardgrass on one-fourth to one-third of the total rice acreage in Arkansas. In Arkansas isopropyl N-(3-chlorophenyl) carbamate (CIPC), used to control barnyardgrass, resulted in increased rice yields. An average net gain of $76 per acre was realized in 10 experiments from 1955 to 1959.

The average rice acreage in California was about 250,000 acres during the past 5 years and the price of rough rice averaged about 4 dollars per 100 pounds. It is estimated that barnyardgrass reduces the yield of rice in California about 1,250,000 bags per year, an annual loss of 5 million dollars. Comparable losses in Arkansas, Louisiana, and Texas cost the U.S. rice industry as much as 20 million dollars annually.

Certain broadleaved weeds, such as coffeeweed, curly indigo, and Mexican weed, reduce the value of rice by lowering the quality of the crop. Mudplantain, a

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serious aquatic weed, has reduced rice yields by 18 to 48 per cent when allowed to compete with rice for the first 4 weeks after seeding.

Cultural methods to control weeds in rice are the predominant methods employed by rice growers in the United States. Adequate seed-bed preparation combined with judicious use of water is vital in a weed-control program. In addition, supplemental use of herbicides can greatly increase the effectiveness of cultural methods.

In 1955 the U.S. Department of Agriculture initiated a research program to develop improved methods of weed control in rice, with special emphasis on the control of weed grasses, at Stuttgart, Arkansas, and Davis, California, in cooperation with the Arkansas and California Agricultural Experiment Stations. The purpose of this paper is to present a brief summary of the significant results of these investigations.

Cultural Methods of Weed Control

Properly managed rotations play an important role in controlling weeds in rice. Rotations such as rice-pasture in Louisiana and Texas, or rice-soybeans-oats in Arkansas, can effectively reduce weed competition in rice. The entire rotation must be kept weed-free to obtain maximum benefits during the rice year. For example, in a rice-soybeans-oats rotation the soybeans may be kept weed-free by proper cultivation and following the oats, which should be kept free of broadleaved weeds with 2,4-dichlorophenoxyacetic acid (2,4-D) or 2-methyl-4-chlorophenoxyacetic acid (MCPA), the land may be summer-fallowed to rid the field of several weed crops. A rotation which includes summer or fall plowing with several disking operations timed to kill weed seedlings is an important step in producing clean rice. Although in Louisiana and Texas a rice-pasture rotation keeps down many weed species, it is not satisfactory in controlling barnyardgrass species. At present, use of clean seed, coupled with proper implementation of a rotation and hand-pulling is the principal means of controlling red rice.

Adequate land leveling, combined with proper construction of levees to permit a uniform depth of irrigation water, is important in a weed-control program. Land leveling is important because it permits maintenance of a uniform depth of water on the field. It also permits more complete surface drainage, which facilitates control of certain aquatic weeds.

Seeding rice in water reduces barnyardgrass infestations. Grass germination is inhibited while the rice grows well under such conditions. However, using water management to control weed grasses has intensified problems with aquatic weeds such as algae and mudplantain.

Judicious flooding of rice when it is in the seedling stage reduces weed infestations. Barnyardgrass may be controlled partially by flooding early to a depth of 4 to 6 inches. The flood must remain on the field for 2 to 3 weeks in order to control barnyardgrass.

Seeding into the water is practised on more than 95 per cent of the rice acreage in Califorfnia because of the control of **Echinochloa crusgalli** and other weeds including **Eleocharis palustris.** If late spring rains cause grass to germinate before planting rice it is necessary to cultivate and let the soil dry before flooding and seeding the rice. Algae and other weeds become serious if the soil has not been allowed to dry before the field is flooded for planting.

Repeated cultivations in the spring at 1- to 3-week intervals prior to seeding rice usually reduces barnyardgrass and other weed infestations. The last cultivation is usually shallow so that viable weed seed will not be brought near the surface of the soil. Seeding the rice on a roughly prepared seedbed to discourage germination of weed seed is employed in many instances.

Time of applying phosphate is very important because this nutrient stimulates the growth of barnyardgrass and other weeds when applied before seeding rice in a dry seedbed. Grass competition may be reduced by applying phosphate to a crop other than rice in the rotation or by delaying application until just before the rice is inundated for the first time.

Time of applying nitrogen to fields of rice infested with weed grasses is important. Barnyardgrass and other weeds are stimulated by applying nitrogen before seeding of rice. When rice is infested with barnyardgrass, delaying nitrogen application until heading of the barnyardgrass reduces competition of weed grasses with rice. If nitrogen is applied while the grass is vegetative, barnyardgrass consumes most of the nitrogen and the competitiveness of grass with rice is enhanced. When weed grass infestations are high, yields of rice have almost doubled by delaying nitrogen application until heading of the barnyardgrass.

In California where soils are thoroughly dry immediately before seeding, rice germinates at the same time as the grass after the field is flooded. Under these conditions adequate fertilizer applied before seeding enables the rice to emerge and grow rapidly and compete with the grass. Phosphate fertilizer applied into standing water stimulates algae and is ineffective on rice. Nitrogen applied into standing water is inefficiently utilized by rice. Under the conditions in California delayed fertilization is not beneficial from the standpoint of weed control.

CHEMICAL METHODS OF WEED CONTROL

Chemical control of broadleaved weeds in rice began with the advent of 2,4-D. It has been estimated that 40 to 60 per cent of the United States rice crop is being sprayed each year with 2,4-D. MCPA, or closely related herbicides.

Control of barnyardgrass and other weed grasses:

In 1955 studies were begun to find a chemical that would selectively kill barnyardgrass in rice. In the Arkansas rice production area, 5 to 10 thousand acres of commercially grown rice were sprayed with isopropyl N-(3-chlorophenyl) carbamate (CIPC) to control barnyardgrass in 1959.

CIPC applied correctly at 6 to 8 pounds per acre has effectively controlled barnyardgrass without injuring rice under Arkansas conditions. Method and depth of seeding; time, rate and volume of application; and water management after application are important management variables in the effective use of CIPC for controlling barnyardgrass in rice.

Rice has little tolerance to CIPC as it is injured when its seedling roots contact the herbicide. In order to kill barnyardgrass and not injure rice, it is necessary to seed rice at a depth of 1 to 2 inches in the soil. Barnyardgrass seed located in the upper inch layer of soil germinate, contact the herbicide, and are killed. The deeper seeded rice is not injured because CIPC is not

readily leached to the 1½-inch depth and therefore the germinating rice seed do not come into contact with a high enough concentration of the herbicide to be injured. In a depth-of-seeding study, CIPC, applied at 6 pounds per acre, reduced stands of rice seeded ½, 1, and 2 inches deep 92, 62, and 13 per cent, respectively. Since drilling provides a more uniform depth of seeding rice than broadcasting, this method of seeding is recommended when CIPC is being used.

Time of applying CIPC is very important for good control of barnyardgrass. Maximum control of barnyardgrass and minimum injury to rice are obtained by applying CIPC when the largest grass is not beyond the first-leaf stage of growth. At this time the rice ranges from pre-emergence to complete emergence. When grass reaches the third- to fourth-leaf stage of growth it is difficult to control. Since soil type, moisture, weather conditions, and possibly other factors influence the comparative time of emergence of rice and barnyardgrass, best results are obtained by basing the time of treatment on the growth stage of the grass rather than on that of the rice.

CIPC, at rates of 2 to 12 pounds per acre, has been applied in various investigations. CIPC, applied under field conditions at 6 to 8 pounds per acre, has given best results from the standpoints of performance, economy, and safety to rice. During a 2-year study the average yields obtained from rice plots heavily infested with barnyardgrass sprayed with CIPC at 0, 4, 6, 8, and 10 pounds per acre were 56, 85, 90, 94, and 96 bushels per acre, respectively.

Water management, after application of CIPC, is very critical during dry weather. When the soil cracks or sun-bakes, moisture is essential to the successful use of CIPC. If rainfall does not occur moisture must be applied by irrigation 2 to 4 days after spraying. Soil moisture must be ample before the barnyardgrass becomes too large or before the chemical is lost by volatilization or decomposition in the soil. In a study in which irrigating occurred 2 days after spraying and flooding occurred 2, 12, and 21 days after spraying, control of barnyardgrass was 56, 85, 61, and 23 per cent, respectively, and yields were 80, 90, 84, and 65 bushels per acre, respectively. Control of barnyardgrass was reduced significantly by delaying application of irrigation water.

Under field conditions, CIPC, may be applied with tractor-drawn or airplane equipment. Regardless of type of equipment used, CIPC should be applied in a total spray volume of not less than 10 gallons per acre. Water is used as the diluent for making the spray solution. Droplet size should be large enough so that the spray is deposited on the surface of the soil. This may be obtained by using low spraying pressure and large spray nozzles.

In the California rice-producing area, CIPC, ethyl N, N-di-n-propylthiolcarbamate (EPTC), and a number of other herbicides have been evaluated for the control of barnyardgrass and other weed grasses. CIPC and EPTC have shown experimental promise, but neither chemical is being used for weed grass control in rice grown commercially.

Control of broadleaved weeds:

Herbicides used for controlling broadleaved weeds in rice include 2,4-D, MCPA, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and 2-(2,4,5-trichlorophenoxy) propionic acid (silvex). These herbicides are applied either as amine or low volatile ester formulations at rates of ½ to 1½ pounds

per acre (acid equivalent). The rate used will depend upon the weed species present and the stage of growth of the rice.

Most of the broadleaved weeds and certain of the sedges mentioned above are controlled by applications of herbicides. Grass weeds are not controlled by post-emergence applications of 2,4-D and related herbicides.

Weeds respond differently to the above herbicides. For example, coffeeweed is very susceptible to 2,4-D and 2,4,5-T but curly indigo is somewhat resistant to 2,4-D and very susceptible to 2,4,5-T. Mud-plantain, however, is more susceptible to 2,4-D than to 2,4,5-T. When several species of weeds varying in susceptibility to a herbicide are present in a rice field, mixtures of herbicides may be used advantageously. This has prompted the use of mixtures of 2,4-D and 2,4,5-T by commercial growers.

The reaction of rice seedlings to 2,4-D depends upon its stage of growth. Very young rice is killed by 2,4-D or related herbicides. Rice is sensitive to 2,4-D until it is about 7 weeks old and during the jointing and booting stages of growth. Rice is most tolerant to 2,4-D when it is 7 to 9 weeks old. Because varieties of rice differ in rate of development, herbicides should be applied according to morphological stage of growth. Rice is least sensitive to herbicides during the late-tillering stage of development, which usually occurs when the rice is 7 to 9 weeks old. Rice sprayed with 2 pounds per acre of 2,4-D was reduced in yields by 24, 2,11, and 22 per cent when the herbicide was applied at early-tillering (4 weeks), late-tillering (8 weeks), jointing (10 weeks), and booting (12 to 14 weeks) stages of growth, respectively.

Rice responds differently to post-emergence herbicides. During the initial 4- to 7- week period of rice development, 2,4,5-T, MCPA, and silvex are less injurious than 2,4-D to rice. Yields were reduced 16, 7, 2, and 0 per cent when 4-week-old rice was sprayed with 2,4-D, MCPA, silvex, and 2,4,5-T, respectively. All these herbicides, however, may cause severe injury to rice when they are applied during the booting stage of growth. Under some conditions 2,4,5-T, MCPA, and silvex are less toxic than 2,4-D to rice when they are applied during the 7- to 9-week "tolerant" stage of growth.

Tractors or airplanes are usually used to apply phenoxy-type herbicides. In small operations, however, spraying may be accomplished by hand with knapsack sprayers. Low volumes of spray are usually used because of the type of equipment employed. Two to 5 gallons of spray per acre is used in airplane applications and 5 to 10 gallons of liquid per acre provides adequate foliage coverage, if tractor-powered ground equipment is used.

When phenoxy-type herbicides are applied at ½ to 1 pound per acre during the "tolerant" stage, method of seeding, water management, fertility, and variety do not appear to have a significant influence on the response of rice to the herbicides. Seeding method, water management, and temperature may have a significant effect on the response of rice to herbicides applied in the "susceptible" stages, especially on rice 3 to 6 weeks old.

Caution should be used when spraying 2,4-D and related herbicides for weed control in rice since these herbicides are very toxic to certain sensitive crops such as cotton and soybeans grown in rice-producing areas. Herbicides applied for weed control in rice may drift to adjacent susceptible crops. Most States regulate spraying of 2,4-D and related herbicides with laws that must be followed closely when rice is being sprayed with post-emergence herbicides.

Summary

The significant results of 5 years of investigations on the control of weeds in the rice-producing areas of Arkansas and California have been discussed. No attempt has been made to present all the technical results of these investigations.

A method of controlling weed grasses in the south-eastern rice-producing area involving the use of CIPC in combination with several cultural management practices has been developed. The combination herbicide-cultural practice was used effectively to control barnyardgrass and other weed grasses on more than 5,000 acres of commercially grown rice in 1959.

In the western rice-producing area, CIPC and EPTC, in combination with various cultural practices, have shown experimental promise for the control of barnyardgrass and other weed grasses; but these herbicides are not presently suggested for commercial use.

Intensive fundamental investigations have been conducted to develop basic information on the use of 2,4-D, MCPA, 2,4,5-T, and silvex for the most effective control of a wide range of broadleaved weeds and sedges with minimum risk of injury to rice. It is estimated that over 40 per cent of the total rice crop in the United States is treated annually with phenoxy-type herbicides for the control of weeds.

Basic and applied studies are being continued to improve current weed-control practices and to develop new herbicides and new improved chemical-cultural methods of controlling weeds in rice.

BREEDING RICE VARIETIES FOR RESISTANCE TO THE VIRUS DISEASE HOJA BLANCA[1]

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Hoja Blanca, or white leaf, was recognized in 1956 as a new rice disease in the Western Hemisphere. The symptoms are similar in many respects to those of the stripe virus disease of Japan.

In view of the serious yield losses from hoja blanca in certain areas of Cuba and Venezuela in 1956, the disease was considered a potential threat to the United States rice crop. For this reason, research studies were initiated in 1957 by the United States Department of Agriculture, in cooperation with the rice experiment stations of Arkansas, California, Louisiana, and Texas and public and private organizations in several Latin American countries. The USDA Hoja Blanca Laboratory at Camaguey, Cuba, was established in

1 Contribution of the Crops Research Division, Agricultural Research Service, United States Department of Agriculture, in cooperation with the Arkansas, California, Louisiana and Texas Agricultural Experiment Stations.

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1957. Varietal differences observed as early as 1956 led to immediate strain testing of many varieties under conditions of natural infection.

Distribution

Hoja blanca, first recognized as a serious new rice disease in 1956 in Cuba, has been found in Venezuela, Colombia, Surinam, Panama, Costa Rica, El Salvador, Guatemala, the Dominican Republic, and British Honduras, as well as in 3 States in the United States. The disease was first found in Florida in 1957, in Mississippi in 1958, and in Louisiana in 1959.

After recognition of hoja blanca as a new rice disease in 1956 and description of pathological symptoms in 1957, it was revealed that the disease actually had been present in Cuba in 1954, in Panama in 1952, and in Colombia as early as 1935.

Symptoms

The symptoms consist of longitudinal white stripes and mottled or nearly white leaves. The panicles emerge incompletely, show abnormal floral parts, and usually are sterile. Unless infected when young, diseased plants are not killed but are shorter than normal ones at the heading stage.

Transmission Studies

Sogota orizicola Muir, a plant hopper, is the only known insect vector for the virus-causing hoja blanca. The virus has not been transmitted from diseased to healthy rice plants by using various manual or mechanical techniques. Negative results were also obtained in seed transmission studies with seed harvested from panicles of diseased plants.

Reaction of U.S.A. Varieties

Varietal tests conducted in nursery rows in Cuba and Venezuela in 1957 showed that leading U.S.A. rice varieties and all U.S.A. commercially grown long-grain varieties were susceptible to hoja blanca. The following minor U.S.A. short- or medium-grain varieties were resistant: Colusa, C.I. 1600; Mo. R-500, C.I. 9155; Asahi, C.I. 8312; Lacrosse, C.I. 8985; and Arkrose, C.I. 8310.

Breeding for Resistance

Frequently, natural infection has not provided adequate disease symptoms for proper classification of material. For this reason screen-house testing techniques are in the process of being developed with the hope that more consistent results will be obtained.

Field-scale production of resistant varieties has demonstrated conclusively that varieties classed as resistant are capable of producing normal or nearly normal yields under heavy disease incidence. This fact was clearly demonstrated in Cuba in 1956 and later by the performance of the Zayas Bazan variety. Later, field-scale production of Lacrosse and C.I. 9416 in Venezuela further substantiated the results observed in Cuba.

During 1957 to 1959, several thousand varieties and selections were tested for reaction to hoja blanca in nursery rows in Cuba, Venezuela, and Colombia. Known susceptible varieties were included at frequent intervals throughout all nurseries to provide an index of the degree of natural infection. A numerical rating scale of 0 to 9 was used. Varieties showing a low incidence of disease symptoms (0-2) were classed as resistant.

During the course of the testing program, most varieties and selections of the USDA World Rice Collection, as well as many hybrid selections from the breeding nurseries of the 4 rice experiment stations, were tested for reaction to hoja blanca.

A number of resistant varieties and selections were grown in uniform nurseries at several locations to determine the reaction of resistant varieties to the virus in different countries. So far, the results obtained from the uniform nursery tests have given no indication of different strains of the virus.

A high level of resistance to hoja blanca was found in many Japonica varieties and in short- and medium-grain varieties carrying Japonica genes. A number of the varieties classified as resistant are listed in Table 1. Lacrosse has consistently been one of the most resistant varieties tested. Several selections developed from crosses between Lacrosse and other varieties have also shown a high level of resistance.

C.I. 9416 is considered to be a valuable source of resistance because of its extremely éarly maturity and good grain shape and appearance. P.I. 215936, introduced from Taiwan under the name Tainan-iku No. 487, has proved to be a good resistant parent variety. It possesses the high-yielding ability of the Japonica varieties and produces a short sturdy-straw under growing conditions in southern United States. Selections with outstanding plant types have been found in crosses between this variety and leading long-grain U.S.A. varieties. Arkrose has also been used as a resistant parent in a limited number of crosses. Colusa, a commercially grown California variety, has been used in numerous crosses as a source of resistance in the development of short-grain varieties adapted to California conditions.

Varying degrees of resistance weré found in long-grain varieties from Cuba, India, Iran, and Peru that have been used in crosses with U.S.A. varieties. The varieties referred to are listed in Table 1. None of these long-grain varieties were satisfactory for mechanized production in the U.S.A. because of weak straw, late maturity, and other undesirable characteristics. Hoja blanca-resistant selections were obtained from most of these crosses, and some reasonably promising plant types, which may possess satisfactory resistance, and which, if not suitable for production, may be valuable sources of resistance in breeding resistant long-grain varieties, have been found.

Reasonably satisfactory short- and medium-grain varieties resistant to hoja blanca that are now available or could be made available to rice growers in a relatively short period have been found. Arkrose has been grown commercially in Arkansas for a number of years and a major part of the several thousand acres grown in 1959 could probably be utilized for seed should the need arise.

In Texas, 650 acres of C.I. 9416 and 150 acres of P.I. 215936 were grown in 1959. These varieties are being considered for release for commercial production. In California the Colusa variety is available in large quantity should it be needed as a resistant variety. Lacrosse has been increased in Louisiana.

Resistant long-grain varieties must come from the breeding programs in progress at the various United States of America rice experiment stations. Many prom-

ising long-grain types are being obtained from crosses involving C.I. 9416, P.I. 215936, Lacrosse, and Magnolia x F_1 of Cross 471, crossed with long-grain varieties such as Rexoro, Bluebonnet 50, Century Patna 231, and Rexano-Red selections. Resistance has also been recovered in backcross plants in which the long-grain varieties were used as recurrent parents. By the end of the 1960 testing year a reasonably large number of promising long-grain selections should be available for yield testing in 1961.

The information reported demonstrates that resistance to the hoja blanca virus disease is controlled genetically and that resistance can be transferred to varieties of all grain types commonly grown in the United States of America.

ACKNOWLEDGEMENT

The authors wish to acknowledge the cooperation of the following individuals:

W. C. Davis, Arrozal Bartes, Jobabo, Cuba;

Dr. Julian Acuna, Ministry of Agriculture, Havana, Cuba;

W. K. Walker, Rockefeller Farms, Valencia, Venezuela;

Gino Malaguti, Ministry of Agriculture, Maracay, Venezuela;

P. R. Jennings, Rockefeller Foundation, Bogota, Colombia; and

Lucy H. de Gutierrez, Inter-American Institute of Agricultural Science, Turrialba, Costa Rica.

Table 1

Rice Varieties, Introductions, and Selections from which Resistance in Hybrids was recovered

Number	Varietal Name	Origin
* C.I. 1600	Colusa	Selection from introduction
C.I. 8310	Arkrose	Caloro x Blue Rose
C.I. 8985	Lacrosse	Colusa-Blue Rose x Shoemed-Fortuna
C.I. 9094		Early short-grain bulk
C.I. 9155	Mo. R-500	Meshibu-Zenith x Gin Bozu-Early Blue Rose
C.I. 9207		Caloro x Blue Rose
C.I. 9209		Bruin Sel. x Zenith
C.I. 9416		Bruin Sel. x Zenith
C.I. 6001	Pandhori No. 4	Introduction from India
+ P.I. 195474		Introduction from Iran
P.I. 195474	Sadri	Introduction from Iran
P.I. 180177	Lambaygue No. 1	Introduction from Peru
P.I. 183331		Introduction from India
P.I. 184675		Introduction from Iran
P.I. 215936	Tainan-iku No. 487	Introduction from Taiwan
None		Selection from Magnolia x F_1 Cross 471

* C.I. refers to accession number of Cereal Crops Research Branch.

\+ P.I. refers to the number under which the strain was introduced into the United States.

NOTE ON GENOM ANALYSIS IN ORYZA SPECIES

Toshitaro Morinaga[1]

Of late the scope of rice breeding has enlarged in view of the breeders' interest in related wild species of rice. The work on the hybridization of cultivated rice O. sativa with wild species and cytological analysis of F_1 hybrids were started by the author in 1934 and the progress of the work in the earlier years was rather slow. Though the work is still not complete the result so far obtained is presented in the note.

Table 1 indicates the number and association of chromosomes in metaphase I of the P.M.C. in the F_1'S of the 18 species hybrids and in the respective parents of the crosses. On the basis of chromosome association, the constitution of each of the species is given in Table 2. The genom of O. australiensis remains still to be analyzed.

Table 1

Number and association of the chromosomes found in metaphase I of the P.M.C. divisions

Crosses I	2n = 24 x 2n = 24	F_1 hybrids
Parents and chromosome association		
O. sativa L. (12 II)	x O. cubensis Ekman. (12 II)	(12 II)
,,	x O. glaberrima Steud. (12 II)	(12 II)
,,	x O. breviligulata Chev. et Roeh. (12 II)	(12 II)
O. sativa L. (12 II)	x O. officinalis Wall. (India) (12 II)	(24 I)
,,	x O. officinalis Wall. (Ceylon) (12 II)	(24 I)
,,	x O. australiensis Domin (12 II)	(24 I)
Crosses II	2n = 24 x 2n = 48	
O. sativa L. (12 II)	x O. paraguaiensis Wedd. (24 II)	(36 I)
,,	x O. latifolia Desv. (24 II)	(36 I)
,,	x O. eichingeri Peter (24 II)	(36 I)
,,	x O. minuta Presl. (24 II)	(36 I)
O. glaberrima Steud. (12 II)	x O. eichingeri Peter (24 II)	(36 I)
O. officinalis Wall (Ceylon) (12 II)	x O. latifolia Desv. (24 II)	(12 II+12 I)
,,	x O. paraguaiensis Wedd. (24 II)	(12 II+12 I)
O. minuta Presl. (24 II)	x O. officinalis Wall. (Ceylon) (24II)	(12 II+12 I)
Crosses III	2n = 48 x 2n = 48	
O. eichingeri Peter (24 II)	x O. minuta Presl. (24 II)	(24 II)
O. latifolia Desv. (24 II)	x O. paraguaiensis Wedd. (24 II)	(24 II)
O. minuta Presl. (24 II)	x O. paraguaiensis Wedd. (24 II)	(12 II+24 I)
,,	x O. latifolia Desv. (24 II)	(12 II+24 I)

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Table 2

Genom constitution of Oryza species

Species	Constitution	Source of Origin
O. sativa L.	12 II AA	Asia
O. cubensis	12 II AA	Cuba
O. glaberrima	12 II AA	West Africa
O. breviligulata	12 II AA	West Africa
O. officinalis	12 II CC	Burma, Ceylon
O. australiensis	12 II (not AA)	Australia
O. paraguaiensis	24 II CCDD	South America
O. latifolia	24 II CCDD	Middle, South America
O. minuta	24 II BBCC	Philippines
O. eichingeri	24 II BBCC	East Africa

SOME ASPECTS OF THE PHYSIOLOGY OF BRONZING

Noboru Yamada[1]

Root system and root damage

According to the observations made at the Bombuwela experiment station, paddy usually grows very well for about thirty days after transplanting, but later growth is retarded, showing (1) dieback of many lower leaves, (2) bronzing, and (3) lodging. This depression and disturbance of plant growth usually seems to be accelerated by top-dressing with nitrogen (sulphate of ammonia).

When the roots of these plants were examined at about heading time, almost all the roots were found to be dead with the exception of a few young freshly developed roots. The roots were discoloured greyish-white, due to the deposit of iron sulphide on the surface of roots.

Paddy growing under normal conditions has usually two different types of roots during the latter part of the growing period, particularly after panicle-primordia initiation: (1) superficial roots with a large number of rootlets, spreading almost horizontally just under the soil surface, which appear like a matted network, and (2) ordinary roots elongating downwards. In the presence of iron and sulphide in the soil, both types of roots are coloured black. But the superficial roots are younger than the other roots, and are more active physiologically. Plant nutrition at the later growing stages is therefore supported more by the functioning of the superficial roots than of the older roots.

Plants showing severe bronzing symptom were found to have no development of the superficial roots. In addition to this, the total number of roots was remarkably small.

[1] Expert from Japan under Colombo Plan deputed to Ceylon Department of Agriculture as Chief Research Coordinator

The cause of root damage is discussed later. Nevertheless, it may be mentioned that when the roots are exposed to a toxic substance they are injured, and their physiological functions are obstructed. However, the influence of root damage on plant growth and plant nutrition varies with the stage of the plant. During the early stage of growth, when the plant has an active rooting ability, the plant as a whole is hardly affected by the root damage, because it can produce a great deal of new roots which take the place of the damaged roots. Consequently, the plant is not affected seriously even though the roots are killed. But as growth advances, the rooting ability decreases, and after the initiation of the "internode elongation", the nutrition of the plant is supported mainly by the roots already developed and which are still active. Under conditions favourable for growth, the plant can produce enough superficial roots to support the later nutrition of the plant. On the other hand, when soil conditions and plant growth are poor, the roots lose their activity faster than roots under good conditions, and the development of the superficial roots is also retarded. The result is growth depression, die-back of the lower leaves, increase in unfruitful tillers, and retarded ripening of grains.

The fact that top-dressing of nitrogen (sulphate of ammonia) aggravates growth retardation and incidence of bronzing can be explained as follows:–

(1) Roots respire continuously and the carbohydrates required are supplied only by the shoot. Sufficient supply of available carbohydrates for root respiration is essential to make the roots resistant to toxic substances. Heavy application of nitrogen results in the shortage of available carbohydrates, because large quantities of carbohydrates are consumed to make up organic nitrogenous compounds from NH_4–N during the process of nitrogen assimilation. Therefore, nitrogen application, through its effect on the carbohydrate supply to roots, can depress the root resistance to toxic substances.

(2) The damage to roots also leads to the retardation of the absorption of nutrients such as silica, potassium and phosphate. But nitrogen NH_4–N is more easily absorbed by the damaged roots. Therefore, application of nitrogen promotes unbalance between these nutrients. For example, symptoms of phosphate or potassium-deficiency are more pronounced with plants supplied with excess nitrogen. Plants which lack nitrogen do not usually show symptoms of phosphate or potassium deficiency even though there is a shortage of these elements in the plant. Balance between these elements and nitrogen within the plant determines the nutritional status of these elements.

Excess of nitrogen and the deficiency of potassium, phosphate and silica thus induced, are responsible for the disturbance of plant growth and incidence of various diseases such as brown spot, sheath blight, and stem rot;

the latter two cause die-back of lower leaves and lodging.

(3) When top-dressing of nitrogen is applied in the form of sulphate of ammonia (134 lb/acre), the SO_4-radical of the fertilizer is easily reduced to H_2S and this accelerates root damage.

Symptoms of bronzing

The symptoms of the so-called bronzing can be classified into several different types:–

(1) Blackish brown small spots on the leaf or the whole leaf becoming dirty brown colour. This seems to be a direct symptom of ferrous iron toxicity, because the same symptom as this can be induced experimentally by exposing roots of paddy to ferrous iron solution or inserting cut leaves into the solution.

(2) Purple coloration appearing in spots or in marginal areas of the leaf apparently a symptom of phosphate deficiency. The occurrence of phosphate deficiency can be explained in the following way. Excessive quantity of ferrous iron absorbed by the plant makes an insoluble product, $FePO_4$ by combining with phosphate. This reaction can take place on the surface of the roots as well as within the plant tissue. Some redox system of tissues and also the oxidation-reduction change of Mn in the tissues can produce the above reaction.

Fe^{++} (Absorbed) ⟶ Fe^{+++}

Redox system of cell ↓
and/or
oxidation by manganese

Fe^{+++} + PO_4 $\underline{Fe\,PO_4}$

↓

Fe^{++} ⟵ Fe^{+++}

On the other hand, the ability of root to absorb phosphate is known to be reduced by the damage of roots under certain conditions.

Symptom similar to the Brown-spot disease

This spot is caused by the fungus **Helminthosporium oryzae**. It is well known that the susceptibility of the plant to this disease is remarkably influenced by the nutritional status of the plant. Deficiency of Mn, K, SiO_2 and Mg makes plants susceptible to the disease. Shortage of Mn, K, and SiO_2 takes place not only from the deficiency of these elements in the soil, but also from root damage.

In this connection, it appears that there is an inverse relationship with the amount of silicification of paddy leaves, and bronzing. Degree of silicification of leaves is expressed by the number of silicified cells counted per microscopic field, and this number can be taken as an indication of the amount of silica contained in the leaves. Degree of silicification is shown in Table 1.

Table 1

Silicification of Paddy Flag Leaves (Bombuwela, Yala 1959)

Variety	No. of leaves tested	No. of measurements* for each determination	Position in leaf			Symptom of bronzing
			Upper	Middle	Basal	
Samba x Mas	5	5	127.8	106.8	57.2	Nil
M 302	5	5	7.2	1.6	0	Severe
M 302**	5	5	2.7	3.4	0	Severe
Devareddiri 26081	5	5	125.1	73.4	53.0	Nil

*Measurements made under microscopic field, ocular 10X, objective 10X

**M-302, grown in sandy area

There is a striking difference in silicification between the plants showing severe attack of bronzing and the plants growing on the adjacent plot which do not show bronzing.

The so-called "bronzing" is a comprehensive term covering a diversity of symptoms. But by distinguishing each different symptom, it should be possible to get a clearer understanding of the cause of the damage.

Cause of root damage and bronzing

From the observation of paddy roots, already described above, it can be considered that the most prevalent damage of roots is due to the toxicity of hydrogen-sulphide. Here there is a contradiction between the fact that the paddy root damage is caused by the toxicity of hydrogen-sulphide, and the statement that the plants show the symptom of bronzing which is caused by excessive ferrous iron; because if excessive ferrous iron is present in the soil, hydrogen-sulphide produced in the soil should be precipitated into the insoluble form of FeS, and therefore the toxicity of hydrogen-sulphide cannot be severe.

In this connection, free ferrous iron and free total iron ($Fe'' + Fe'''$) content of the top soils sampled from the bronzing and non-bronzing plots of sandy and boggy areas were estimated (Table 2). The free iron content of these soils is not particularly high. In some places free iron content in the soil seems to be insufficient to prevent the root damage due to hydrogen-sulphide. Then there arises a question why bronzing due to excessive iron occurs in such soils.

The soil profile of the "bronzing test plot" where bronzing is exhibited very severely, and is accordingly used for the varietal test against bronzing, suggested that the underground water might be the source fo excessive ferrous iron. The soil profile consisted of (1) top layer 20 cm. deep, coloured black with organic matter. The successive layers below the top layer were; (2) sandy soil 30 cm. deep with black spots of organic matter; (3) 20 cm. layer of sand coloured brown with iron and (4) "Kirimatta" or white clay layer of 15 cm. depth. It is quite possible that the underground water with high content of iron, originates from the high land close to the

field, and flows horizontally above the impenetrable "Kirimatta" (white clay) layer.

The seasonal changes of the level of this underground water as well as the iron content of the successive layers of the soil are now under study. The contradiction described above may be partially accounted for by the fact that though the soil itself is not rich in iron, there is a possibility of excessive iron being supplied to the plants from the underground water. In some places the other possibility is that excessive iron may come from the irrigation water and this has to be investigated.

Table 2 (a)

Fe'' and Fe''' content in soils (mg/g. soil dry weight)

Location	Soil	26. Oct.			6. Nov.			20 Nov.			Bronzing 20. Nov.	Remarks
		Soil pH	Fe'' mg/g	$Fe''+Fe'''$ mg/g	Soil pH	Fe'' mg/g	$Fe''+Fe'''$ mg/g	Soil pH	Fe'' mg/g	Fe''' mg/g		
1	Boggy	5.9	3.47	3.47	6.0	2.16	3.15	6.2	1.54	2.34	–	
2	,,	5.9	2.68	2.72	6.0	1.97	4.54	5.9	1.37	2.23	–	
3	,,	5.9	3.37	3.37	6.0	3.38	4.54	5.9	1.81	2.38	–	
4	,,	6.0	2.51	2.51	6.0	2.06	2.89	6.0	1.18	1.53	–	
5	Sandy	6.2	0.05	0.11	6.1	0.03	0.08	5.1	trace	0.08	–	
6	,,	6.5	2.15	2.81	6.8	1.67	2.47	7.6	1.48	1.65	–	Lime applied
7	,,	6.2	0.49	0.52	6.4	0.54	1.09	6.3	0.88	0.82	Severe	
8	,,	–	–	–	–	0.91	1.46	6.4	0.91	1.05	Severe	

Table 2 (b)

Fe'' and Fe''' content in soil water (mg/g water)

Location	Soil	26.Oct.		6.Nov.		20.Nov.	
		Fe'' mg/g	$Fe''+Fe'''$ mg/g	Fe'' mg/g	$Fe''+Fe'''$ mg/g	Fe'' mg/g	$Fe''+Fe'''$ mg/g
1	Boggy	1.72	1.72	1.86	2.73	1.32	2.00
2	,,	2.91	2.95	1.74	4.00	0.83	1.35
3	,,	2.30	2.30	2.58	3.46	1.17	1.54
4	,,	1.88	1.88	1.41	1.98	1.20	1.57
5	Sandy	0.07	0.15	0.13	0.32	trace	0.22
6	,,	3.01	3.94	4.98	7.37	2.78	3.09
7	,,	0.93	0.99	0.83	1.68	1.82	1.68
8	,,	–	–	3.37	5.43	2.59	2.97

(Note: Method of iron determination: Extracted with 0.2% $ALCL_2$ acetate buffer solution of pH 4.5, and iron is determined by O-phenanthrolin. Fe content in soil water: Assuming that all iron in the soil determined here is present in the soil water, iron content is expressed on the water basis).

On the other hand, Table 2 seems to indicate quite another possibility in regard to the cause of bronzing. There is no relation between the occurrence of bronzing and the iron content of the soil. For example, boggy soils contain more ferrous and ferric iron and have lower pH values than sandy soils, but plants exhibit no bronzing at all, while on some sandy soils bronzing is severe. This fact indicates that the direct cause of bronzing is not iron. Presence of some other factor or factors induce root damage and cause bronzing as a result perhaps according to the process described earlier.

All the observations and results of experiments seem to indicate that the bronzing due to excessive iron is only one aspect of the wide problem of root damage and malnutrition of the paddy. The poor performance of paddy in the Wet Zone low country is accounted for by the incidence of various diseases and root damage caused by the unsatisfactory condition of the soil.

Differences in the cause of root damage and so-called bronzing in different places (with different kinds of soil and different topographical characters) should be examined.

SOME PROBLEMS ON MANAGING RICE FARMS IN NAKORN PATHOM PROVINCE, THAILAND

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Prayard Chandrapuang[2]

Rice farmers in Thailand have been able to produce the best quality rice varieties. During the World Rice Contest in Canada in 1932, Thai rice was awarded the first, second, third, and other eight prizes out of a total 20 prizes. For a number of years, the quality of Thai rice has been recognized in the world market. Its export constitutes the backbone of the nation's economy.

In spite of producing high quality rice, the rice farmers in Thailand are not economically better than their counterparts in other Asian countries. Only one crop of paddy is grown annually on most of the farms under the prevalent rainfall conditions. Rice being the staple food, no rice eating country can afford to raise its price. The rich generally consume less rice but more meat or dairy products, while the poor consume more rice. So the demand for rice becomes inelastic. It appears that there is a ceiling in the expansion of rice economy unless other enterprises are

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combined with the mono-cultural system of farming.

To understand better the economic conditions of the rice farmers and their management problems, the Division of Agricultural Economics of the Ministry of Agriculture in Thailand conducted a pilot survey between 1 April 1955 and 31 March 1956 by sending four field officers to supervise 34 rice farmers in Nakorn Pathom Province of the Central Plain in keeping farm accounts. As acknowledged in the Division's report,[1] the small number of farms, the short period of one year taken for the survey, the reluctance of the farmers to maintain book-keeping, and the use of simplified account books for trial purpose; all these have to some extent, limited the representativeness of the data coverage. However, it is believed that supervised farm account is a good practice to keep reliable records in the less-developed countries and this practice should be improved and expanded. By using the available information contained in these 34 farm accounts, this paper attempts to present some problems related to the management of rice farms in the area concerned. The findings of this study may also be used as a basis for comparison on the management aspects between rice farms in Nakorn Pathom Province and other provinces in Thailand, or even other rice producing countries in the Far East.

The Optimum Size of Farm

The size of these 34 farm varies from 5 to 62 rai, with an average of 28 rai.[2] Data shown in Table 1 do not suggest any significant difference in paddy yield per rai between small and large farms. But the total value of farm products per rai in the small farms is much higher than that of the large farms. In the case of the smallest size group of farms, it is even more than double than that of the largest size group. Since the paddy yield is almost the same, the difference in total value of farm products per rai comes from the raising of other crops and livestock. This indicates the possibility that the land use can be improved by adopting intensive cultivation as in the small farms.

In his book (published in Thai language in 1958) on "**A Study of Farmers' Indebtedness and Paddy Marketing in the Central Plain**", Dr. Udhis Narkswasdi, Professor of Agricultural Economics of Kasetsart University, Bangkok, by analyzing 3,000 farm records, states that the average yield of paddy per rai on the small farms is higher than that of the large farms, in which case, the total value of farm products per rai of the small farms will become much higher than that of the large farms.

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[1] **Report on Economic Survey of Rice Farmers in Nakorn Pathom Province, During 1955-56 Rice Season**, published by the Division of Agricultural Economics, Office of the Under-Secretary, Ministry of Agriculture, Bangkok, Thailand.

[2] 1 rai is equal to 0.16 hectare or 0.395 acres.

Table 1

Yield of Paddy and Total Value of Farm Products per Rai according to Size of Farms

Size of Farms (rai)	Average Size (rai)	No. of Farms	Yield of Paddy per rai [1] (Tang)	Total Value of Farm Products per rai [1] (Bahts)
1.1 – 10.0	6.0	5	25.8	754
10.1 – 20.0	17.6	7	27.2	448
20.1 – 30.0	26.7	10	27.2	404
30.1 – 40.0	35.3	5	25.5	345
40.1 – 62.0	50.7	7	28.8	323
Average	28.0	–	27.1	440
Average of the Central Plain	30.8 [2]	–	26.3 [3]	
Average of the Kingdom	25.1 [2]	–	26.1 [3]	

Although the earnings per unit of land is high, farmers having less than 30 rai have to depend on non-farm income by seeking jobs outside either as wage labourers or as other professional workers in order to make both ends meet. (Table 2). With the present state of farming technique and the prevalent price level, it is perhaps correct to state that (1) it is definitely uneconomical to operate a farm under the size of 10 rai and (2) a full-time rice farmer in Nakorn Pathom Province should operate a farm size of 30 rai (7.5 acres) or more. If intensive cultivation is adopted, a farmer with the present national average size of 25 rai, can maximize his income to have a better standard of living.

Table 2

The Financial Position of Rice Farmers According to Size of Farm

Size of farms (rai)	Farm income (Bahts)	Non-farm income (Bahts)	Total income (Bahts)	Total expenses (Bahts)	Financial position (Bahts)
1.0 – 10.0	4,590	582	5,172	7,590	– 2,418
10.1 – 20.0	7,920	3,075	10,995	8,824	2,171
20.1 – 30.0	10,657	2,108	12,765	11,812	953
30.1 – 40.0	12,106	165	12,269	10,575	1,694
40.1 – 62.0	16,654	651	17,305	13,530	3,175

1 1 tang of paddy is equal to 10 kgs. The price of paddy per tang is 10 Bahts.
1 Baht is approximately equal to U.S. 5 cents.

2 **Thailand Economic Farm Survey, 1953**, Division of Agricultural Economics, Ministry of Agriculture, Thailand, Table 20.

3 Ibid. Table 40

The Efficient Use of Labour

The average size of family in these 34 farms is 6 persons. Of them, 2 persons are under the age of 14 years, 3.6 persons are in the age between 14 and 59 years, and only 0.4 person is above the age of 60 years. Considering the working capacity of female and child labour, the average labour force per farm is approximately 3 man equivalents.

According to the book-keeping data, as many as 16.3 days are required to grow one rai of rice, or 41 days per acre. One day consists of 8 working hours. With rice as the main crop, one farm, on the average, requires 462 days for paddy cultivation, 118 for other crops, and 177 days for livestock, with a total of 697 working days per year (Table 3).

Table 3

Monthly Distribution of Labour Use per Farm (days)

Month	Paddy	Other crops	Livestock	Total
April	4	26	12	42
May	17	20	10	47
June	55	7	9	71
July	97	4	8	109
August	63	5	8	76
September	45	4	9	58
October	21	7	10	38
November	18	4	10	32
December	83	3	8	94
January	53	4	10	67
February	4	14	11	29
March	2	20	12	34
Total	462	118	117	697

In terms of the present cultivation practices, the available family labour is sufficient to take care of the normal load of farm work except in the months of July and December, the time of transplanting and harvesting, when hired labour is required. It is clear therefore that in the rest 10 months, farm labour is not fully utilized. This uneven distribution of labour use calls for (1) diversified farming with proper combination of enterprises, (2) farm work simplification and (3) more outside work, all of which, if accomplished, will not only utilize the available labour more efficiently but also reduce the unit cost of production of farm crops and livestock and give higher farm returns.

The Importance of Family Satisfaction

To rice farmers, farming means both business and a way of living. As a business, they have to consider the input-output relationship in the use of farm resources. As a way of living, they work for the benefit of family satisfaction. In small farm economy, it is difficult, if not impossible, to draw a clear line of demarcation between farm and home management.

By grouping these 34 farms according to their income (Table 4), it is noted that (1) rice farmers in the Nakorn Pathom Province require an annual income of 10,000 Bahts or US$ 500 to support a family without running into debts, and (2) out of the average total expenses, food occupies

the highest percentage (43%), the others next (30%) and farm operations least, (27%) (Table 5). With limited data, average expenses can be roughly divided into three major items: farm operations, food, and the others. Expenses on farm operations include seeds, manuring, depreciation on implements and farm houses, hired labour, rental, interest on capital investment, taxes, etc. Expenses on food include rice, meat and fish products, vegetables and fruits, and other food. Expenses on the others include clothing, education, medical care, transportation, entertainments, and miscellaneousness.

As both food and the others are meant for family satisfaction, they constitute 73 per cent of the total expenses. The importance of family satisfaction cannot be over-emphasized.

Table 4

The Financial Position of Rice Farmers by Income Groups

Income (Bahts)	No. of farms	Average income (Bahts)	Average expenses (Bahts)	Financial position (Bahts)	Average size (rai)
2,000 – 7,000	6	4,881	6,562	– 1,681	9
7,001 – 10,000	7	8,691	9,571	– 894	24
10,001 – 13,000	9	11,877	10,601	1,276	32
13,001 – 17,000	7	16,558	14,389	1,744	35
17,001 – 23,000	5	20,604	12,561	8,041	40

Table 5

Expenses by Income Groups

Income (Bahts)	Expenses (Bahts)							
	Total	%	Farm operations	%	Food	%	Others	%
2,000 – 7,000	6,562	100	947	14	3,324	52	2,291	34
7,001 – 10,000	9,571	100	1,506	16	4,798	50	3,267	34
10,001 – 13,000	10,601	100	2,429	23	4,867	46	3,305	31
13,001 – 17,000	14,389	100	4,800	33	5,714	39	4,395	28
17,001 – 23,000	12,561	100	4,739	38	4,439	35	3,385	27
Average	10,739	100	2,884	27	4,628	43	3,328	30

It is further noted that when income moves to higher level, expenses increase too (Table 5). The increase in expenses, however, varies among these three major items. The expenses on farm operations continue to increase as income level increases both in actual amount and in percentage because of its relation to farm size. But the percentage of food expenses decreases significantly as income level increases. It is 52 per cent of the total expenses when income is low and 35 per cent when income is high. Since food includes mostly rice, it can be taken that the demand for rice is quite inelastic. At the present consumption level, the

amount of expenses on the others increases with higher income levels, though in percentage of the total expenses, it is slightly reduced. This shows that, when income level increases, farmers will spend more money on education, transportation, entertainment, and others. For these 34 farms, it appears that, except farm operations, the total amount spent on food and the others begin to reduce after reaching certain limit, say Bahts 17,000. Above this limit, the actual expenses become less.

Tables 4 and 5 suggest that (1) the prime goal of these rice farmers is to maximize family satisfaction, (2) government should assist the rice farmers of the low income group for improving their farm operations and for their earning more non-farm income, and (3) farmers in the high income groups have sufficient savings which can be used to invest in agricultural improvement, if properly encouraged.

The Problem of Indebtedness

As many as 12 farms out of 34 farms cannot manage to pay all cash expenses. They have to rely on loan from the private sources. The interest rates paid for the loan vary from 20 to 40 per cent[1]. The difficulty in obtaining loans also leads to delay in farm operations, periodic malnutrition, and unnecessary family troubles. Supply of cheap credit in time by the government agencies such as cooperatives and/or farmers banks is badly needed.

Of the average total expenses, cash payment occupies 60 per cent. Table 6 shows the monthly distribution of cash expenses between farm operations and family satisfaction (food and the others). It indicates that farmers have cash expenses every month.

Table 5

Monthly Distribution of Cash Expenses (Bahts)

Month	Farm operations	Family satis-faction	Month	Farm operations	Family satis-faction
April	138	439	November	76	382
May	163	467	December	114	413
June	161	348	January	131	425
July	268	334	February	76	380
August	120	381	March	185	409
September	103	424			
October	76	398			
			Total	1,611	4,800

The hardship in cash payment may arise from the fact that the main source of farm income from the sale of rice may not be sufficient. After harvest, a part of the paddy is paid as rent, a part of it is sold for paying debts, and a part of it is kept for family use. The actual quantity of paddy left for sale varies from farm to farm. Other products raised at farm in small quantities have no commercial value. This proves that farmers have a regular burden of monthly cash expenses and lack other seasonal sources of cash income. The solution to this problem as experienced in other countries, will depend largely on the introduction of diversified type of farming.

1 Thailand Economic Farm Survey, 1953. Table 47.

Summary

Analyzing the data collected from 34 supervised farm accounts, this study intends to present some problems on the management of rice farms in Nakorn Pathom Province, Thailand. The findings show that, under the present state of farming and the prevalent price level, the optimum size of a full-time rice farm in the area studied should be 30 rai. The existing mono-cultural type of farming cannot utilize the available farm labour efficiently. As many as 10 months out of one year, farm labour is under-employed. The lion's share of total income per farm is to maintain or improve the level of family satisfaction (for food and other necessities). The lack of other seasonal sources of incomes to meet the regular cash expenses, necessitates the borrowing of money from private sources at high rates of interest. The possible solution to meet these problems is to introduce technological improvements which will enable the rice farmers to reorganize their farm resources by changing the mono-cultural to diversified type of farming. Government assistance for supplying cheap credit is urgently needed.

PRINTED at BAMRUNG NUKOULKIT PRESS
83 Bumrung Muang Rd.
Publisher: Nai Kong Yuvanathemeya B.E. 2503